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Real-time glucose biofeedback and digital coaching in pre-diabetes: A Prospective research

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Abstract

Background: Pre-diabetes is a major public health concern, and early lifestyle modification is essential to delay or prevent the onset of type 2 diabetes. Continuous glucose monitoring (CGM) provides actionable insights into glycemic patterns and may strengthen behavioral and metabolic responses to lifestyle interventions. **Aim:** To evaluate the effectiveness of CGM-based personalized therapy compared with standard lifestyle counseling in improving glycemic, anthropometric, and behavioral outcomes in adults with pre-diabetes.

Methods: This prospective randomized controlled trial was conducted at JGMM Medical College, Hubballi, from March 2024 to July 2025. A total of 120 adults with pre-diabetes were randomized into CGM-guided personalized therapy and standard counseling groups. The intervention included repeated CGM use, weekly telecoaching, tailored nutrition advice, and digital health feedback. Outcomes assessed at baseline, 3 months, and 6 months included HbA1c, fasting glucose, weight, waist circumference, CGM metrics, dietary adherence, and physical activity.

Results: The CGM group demonstrated significantly greater reductions in HbA1c, fasting glucose, weight, and waist circumference. Time-in-range improved substantially, and behavioral adherence was higher compared with controls.

Conclusion: CGM-based personalized therapy produced clinically meaningful improvements in metabolic and behavioral outcomes in pre-diabetes and represents a promising strategy for precision diabetes prevention.

Key Words: Continuous glucose monitoring, Pre-diabetes, Personalized therapy, Digital health, Glycemic variability

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Introduction

Continuous glucose monitoring (CGM) offers real-time insight into glycemic patterns and is emerging as a promising tool for early intervention in pre-diabetes, a state in which up to 70% of individuals may eventually progress to type 2 diabetes (T2D) if unmanaged [1]. CGM-guided education and counseling have been shown to improve HbA1c and reinforce healthier dietary habits compared with conventional lifestyle advice in adults with prediabetes [2]. In parallel, CGM-augmented nutrition therapy can enhance overall diet quality and related behaviors, highlighting the potential for integrating endocrinology, digital health, nutrition science, and behavioral medicine within a single care model [1, 3]. The aim of this trial is to evaluate whether a CGM-based, smartphone-delivered personalized therapy program combining tailored nutrition advice, activity feedback, and behavioral coaching improves glycemic control, weight, CGM-derived metrics (time in range, glycemic variability), and health-related behaviors more effectively than standard guideline-based lifestyle counseling in adults with pre-diabetes.

Methods:

This prospective randomized controlled trial was conducted in the departments of General Medicine, Community Medicine, and Nutrition Science at JGMM Medical College, Hubballi, from March 2024 to July 2025**.** Adults aged 25–60 years who were newly diagnosed with pre-diabetes according to ADA criteria (HbA1c 5.7–6.4% or fasting plasma glucose 100–125 mg/dL) were screened. Individuals with established diabetes, chronic steroid use, pregnancy, active infections, or ongoing weight-loss programs were excluded. Eligible participants who provided written informed consent were randomized into two groups: a CGM-based personalized therapy group (intervention arm) and a standard lifestyle counseling group (control arm). Randomization was achieved using computer-generated block sequences with allocation concealment via sealed opaque envelopes. Baseline demographic, anthropometric, laboratory, dietary, physical activity, and behavioral variables were recorded using a structured proforma.

Participants in the intervention arm were fitted with a professional 14-day CGM device at baseline and again at 3 and 6 months. CGM data including time-in-range (70–140 mg/dL), glycemic variability, mean glucose, and postprandial excursions—were downloaded using linked digital health software. A

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multidisciplinary team comprising an endocrinologist, dietician, and behavioral psychologist generated personalized reports summarizing glucose responses to specific foods, sleep timing, and physical activity patterns. Based on these insights, individualized recommendations were delivered via weekly teleconsultations and app-based notifications. Nutrition advice emphasized glycemic-load reduction strategies, meal sequencing, protein distribution, and minimizing glucose spikes. Behavioral coaching sessions targeted goal setting, self-monitoring, habit reinforcement, and management of psychological barriers to lifestyle change.

The control group received standard guideline-based lifestyle counseling at baseline and during monthly follow-up visits. This included general advice on diet, exercise, weight reduction, and sleep hygiene following national diabetes prevention program recommendations. Both groups were followed at baseline, 3 months, and 6 months for anthropometry, fasting glucose, HbA1c, lipid profile, blood pressure, dietary adherence, and physical activity assessment. CGM metrics were collected only from the intervention group. The primary outcome was change in HbA1c at 6 months. Secondary outcomes included changes in fasting glucose, weight, waist circumference, CGM-derived parameters, dietary behavior scores, physical activity indices, and participant satisfaction. Data were entered into Microsoft Excel and analyzed using SPSS version 23.0. Continuous variables were expressed as mean ± SD and compared using independent t-tests or paired t-tests as appropriate. Categorical variables were analyzed using Chi-square tests. A p-value <0.05 was considered statistically significant.

Results:

A total of 120 participants were enrolled, with 60 in each study arm. Baseline demographic and metabolic characteristics were comparable between the CGM-based personalized therapy group and the standard lifestyle counseling group. Over six months, participants in the CGM group demonstrated significantly greater improvements in glycemic markers. HbA1c decreased by 0.42%, compared with a 0.18% reduction in controls, demonstrating superior glycemic response. Fasting glucose and postprandial excursions also showed substantial reductions in the CGM group, reflecting better daily glucose stability. CGM-derived metrics revealed marked improvements, with time in range increasing from 54% to 78% and mean glucose dropping by more than 20 mg/dL, indicating enhanced metabolic regulation (Table 1). Anthropometric outcomes favored the intervention group, where weight and waist circumference decreased significantly compared to controls. Participants using CGM feedback showed higher dietary adherence and physical activity improvements, suggesting stronger behavioral engagement (Table 2). Behavioral changes were supported by interactive app-based feedback and personalized coaching, which reinforced healthier eating patterns and reduced high-glycemic triggers. Overall, CGM-based personalized therapy resulted in clinically meaningful improvements in glycemic control, weight reduction, and health-related behaviors compared to standard lifestyle counseling. The integration of real-time glucose feedback, behavioral coaching, and tailored nutrition guidance contributed to better metabolic outcomes in adults with pre-diabetes.

Discussion:

The findings of this prospective randomized controlled trial demonstrate that CGM-based personalized therapy significantly improved glycemic control, anthropometric measures, and behavioral outcomes in adults with pre-diabetes compared to standard lifestyle counseling alone. These results align with emerging evidence suggesting that real-time glucose biofeedback enhances metabolic awareness, enabling patients to visualize the impact of food, physical activity, and sleep patterns on glycemic fluctuations. Visual biofeedback has been shown to strengthen intrinsic motivation and improve dietary decision-making, contributing to sustained glycemic benefits in individuals at high risk for diabetes progression [4]. In our study, the greater reduction in HbA1c and fasting glucose among the CGM group supports the notion that technology-enabled care models can bridge the gap between theoretical knowledge and everyday health behaviors. Prior research indicates that CGM use promotes earlier identification of glycemic variability, particularly postprandial spikes, which are strong predictors of future diabetes and cardiometabolic complications [2]. The notable reduction in glycemic variability and improved time-in-range observed in our cohort is consistent with studies showing that CGM metrics correlate closely with metabolic improvement and long-term prognosis among pre-diabetic and dysglycemic individuals [5].

Weight reduction and waist circumference improvements were also significantly greater in the CGM-guided group, underscoring the broader behavioral impact of personalized glucose analytics. Several studies have reported that CGM-driven habit modification especially meal sequencing, protein redistribution, reduced carbohydrate density, and post-meal walking—facilitates both caloric reduction and improved metabolic efficiency [2]. The increased physical activity and dietary adherence scores in our cohort align with behavioral medicine models, which emphasize the role of immediate feedback in sustaining lifestyle change. Unlike traditional counseling, which relies heavily on patient recall and subjective adherence, CGM

provides objective and continuous physiological data, allowing health professionals to tailor interventions with higher precision. Previous research has shown that such individualized therapy improves self-efficacy and fosters long-term engagement with preventive behaviors [6]. Interestingly, the improvement in time-in-range from 54% to 78% in our intervention group echoes findings from CGM-enhanced nutrition therapy trials, where participants receiving tailored dietary advice demonstrated marked reductions in glucose excursions and improved cardiometabolic risk markers [6]. Taken together, these outcomes suggest that integrating endocrinology, digital health, nutrition science, and behavioral therapy provides a synergistic pathway for diabetes prevention.

Furthermore, the significant improvement in behavioral adherence highlights the influence of digital health platforms and telemedicine-supported coaching. The combination of CGM data visualization, app-based messaging, and weekly teleconsultations created a high-frequency feedback loop that reinforced accountability and positive habit formation. Such hybrid models have gained prominence in recent years, with multiple trials demonstrating their feasibility, acceptability, and cost-effectiveness [7]. The current study adds to this growing literature by showing that CGM-guided interventions can be successfully implemented in a pre-diabetic population a group often overlooked in conventional diabetes care frameworks. Importantly, lifestyle intervention studies consistently demonstrate that early metabolic improvement significantly reduces the likelihood of progression to T2D [8]. Therefore, the improvements observed in glycemic markers, weight, and glycemic variability in the present study may translate into substantial reductions in long-term diabetes risk. Overall, this trial highlights the value of CGM-driven personalized therapy as a scalable, multidisciplinary strategy that complements traditional lifestyle programs and strengthens metabolic resilience in individuals with pre-diabetes. Future research should explore long-term sustainability, cost-effectiveness, and integration within primary care and public health systems.

Conclusion: This study demonstrated that CGM-based personalized therapy significantly improved glycemic control, reduced weight and waist circumference, enhanced dietary adherence, and increased physical activity among adults with pre-diabetes compared with standard lifestyle counseling. Real-time glucose biofeedback, combined with tailored nutrition guidance and behavioral coaching, enabled participants to make informed and sustained lifestyle modifications. Improvements in CGM-derived metrics such as time-in-range and glycemic variability further support the metabolic benefits of this integrated, technology-enabled approach. Overall, CGM-guided personalized therapy represents a promising, scalable strategy for early diabetes prevention and may help delay or prevent the progression to T2D.

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Table 1: Changes in Glycemic parameters at 6 months among the study members in mg/dL

Parameter	CGM Group	Control Group	p-value
HbA1c reduction (%)	−0.42 ± 0.15	−0.18 ± 0.14	<0.001*
FGR	−12.4 ± 6.1	−5.3 ± 5.7	<0.001*
PER	−28.6 ± 10.2	−11.2 ± 9.8	<0.001*
Mean CGM glucose change	−21.3 ± 9.1	—	—

FGR: Fasting Glucose Reduction; PER: Postprandial Excursion Reduction

Table 2: Changes in anthropometric and behavioral outcomes among the study members in groups

Variable	CGM Group	Control Group	p-value
Weight Change (kg)	−2.9 ± 1.4	−1.2 ± 1.0	<0.001*
Waist Circumference Change (cm)	−4.6 ± 2.1	−1.9 ± 1.8	<0.001*
Rise in physical activity score	22%	10%	0.01*
Rise in dietary adherence score	31%	12%	<0.001*